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# **RESEARCH PAPER**

# REML/BLUP to estimate GxE interaction in co-ordinated wheat trials

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**Abstract :** Significant linear trend has been observed for wheat production under irrigated timely (IT) and late (IL) sown conditions along with marginal improvement for restricted irrigation (RI) timely sown wheat trials for Northern Western Plains Zone of country. Production elevated to the level of 57, 50 and 49q/ha for irrigated timely, late sown and RI timely sown trials. Significant values of intercept at 0.01 per cent for first two conditions along with significant value for third condition. More over significant values ( at P< 0.005) of slope for linear trend exhibited by irrigated timely and late sown trials with significant change at large values of probability for remaining condition. Desirable small value of CV had been portrayed by irrigated timely and late sown trials as compared to large value for restricted irrigated condition. Average production was 51.6q/ha, 42.3q/ha and 45.6q/ha in 2008-09 and by the end of period 0.62, 0.91 and 0.04 quintal yield could be added in subsequent trials, respectively.

Key Words : Mixed model analysis, REML, BLUP, FA

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#### **INTRODUCTION**

Multi location trials of wheat crop are conducted under coordinated system across the country (Mohan *et al.*, 2017). Salient findings of these trials assist to recommend the cultivation of promising genotypes for specific and general conditions across various agro climatic zones of India (Kleinknecht *et al.*, 2013). Mostly, averages at site and across sites calculated to judge the performance of genotypes. Least squares procedure estimates the genotypes yields for the balanced field designs. However, distribution of error term in field

\* Author for correspondence: <sup>1</sup>CIMMYT, Mexico <sup>2</sup>CIMMYT Regional Office for Asia, New Delhi, India layouts is often more complex as that of in standard linear models analysis (Piepho *et al.*, 2008). Best linear unbiased predictor (BLUP), as a technique for predicting random effects proved numerous applications in field experimentations to estimate fixed and random effects of genotypes, environments and interaction effects (De Pelegrin *et al.*, 2017). This improves *per se* performance of prediction produce as compared to the ordinary least squares approach (Baretta *et al.*, 2017). Mixed models had been utilized as important alternative analytical approaches to overcome limitations of the fixed effects approach (Crespo *et al.*, 2018). Moreover, wheat breeders have paid little attention to this important aspect of multi environments testing. Consequently genotypes averages are generally used regard less of the situations.

Restricted maximum likelihood (REML) method had been found a standard to estimate variance components / genetic parameters with working mixed model (Gustavo et al., 2017). For mixed models, the Best Linear Unbiased Predictor (BLUP) is near the phenotypic average observed for the true genotypic value of the individual, which is a property of an accurate estimator (Torres et al., 2015). BLUP can be used for both the selection of superior individuals and the estimation of future generations' gains (Smith et al., 2015). Modeling GxE by factor analytical (FA) had been utilized for large number of crops as this tool uses the leading principal components of the variance-covariance GxE interaction matrix and accounts for the maximum amount of variation with a reduced number of parameters, yielding a more parsimonious variance-covariance structure (Kelly et al., 2007; Burgueno et al., 2008 and Cullis et al., 2014). Need was felt to perform study based mixed effect models that can increase the accuracy of the selection process of wheat genotypes subsequently results in greater genetic improvement.

## MATERIAL AND METHODS

North Western Plain Zone of India comprises of the parts of sub-humid Sutlej-Ganga Alluvial Plains and arid western plains, which comprises Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), Western Uttar Pradesh (except Jhansi division and hilly areas), parts of Jammu and Kashmir (Jammu and Kathua districts) and parts of Himachal Pradesh (Paonta Valley and Una districts). Wheat is cultivated for three broad cultural conditions, viz., timely sown irrigated, late sown irrigated and timely sown restricted irrigation in major wheat zone. The Experimental Design was Randomized Blocks in three replicates. The advanced varietal trials under irrigated timely and late sown with restricted irrigated timely sown conditions were considered during the period 2012-13 to 2017-18 growing seasons in the major locations of the zone. Moreover, the details of genotypes and locations were reflected in table for completeness.

Estimation of the variance parameters carried out by using residual maximum likelihood (REML) along with estimation / prediction of the fixed as well as random



effects (Eileen *et al.*, 2015). Quite popular and widely cited ASReml-R package was exploited to fit models which use the average information algorithm for REML. Implementation of Factor Analytic approach in ASReml-R package handles the situations of where rank of interaction matrix is of less than full rank. Under Multi Environment Trials, g genotypes were evaluated in e environments and analysed as per model (Resende *et al.*, 2004).

$$y_{ijk} = \mu + \tau_i + \delta_j + (\tau \delta)_{ij} + \gamma (\delta)_{jk} + \varepsilon_{ijk}$$

Yijk	yield of k replication of ith genotype in j-th environment	μ	overall mean	$\tau_{i}$	Effect of genotype	δ <sub>j</sub> e	Effect of environment
$(\tau\delta)_{ij}$	Interaction effect	γ (δ) <sub>jk</sub>	Effect of k-th replication in j-th environment	ε <sub>ijk</sub>	Random error		

i=1,2,3,....g;j=1,2,3,....e;k=1,2,3,....r

# **RESULTS AND DISCUSSION**

Highly significant change in wheat production had been observed during the studied period for irrigated timely, late sown and restricted irrigated timely sown trials in a major wheat producing zone of the country as reflected in ANOVA Tables (4, 5 and 6). Large values

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IndextPBV63PG120PG200PG802PG80	R12*2/3/JUP//PAR214)	/AE.SQ.(320)/3/CUNNI	RO3*PbW568/3/PBW621)	M/HD2278)	KALYANSONA)	KALYANSONA)
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(PBW621/3/TR01/6%1000(GRACKLEMD2894)(DBW14/H0(KAUZ/ALTAR84/AG05/0(M908/PBW534)(CHIR/3/SIREN/ALTCET/4*PBW343/2*PE233/HU4680MLA/KAUZ/HUTES)AR84W201/5'PBW621/3/TR16*AVOCET/4*PBW3437*PBW62172*PBW62172*PBW62172*PBW621	PBW763	HD3226	HD3086 ©	DPW621-50©	DBW95	WH1139
CET/4*PBW334/2*PI273//HUW680MILAN/KAUZ/HUTES)AR8)WG1/5*PBW32/17SS </td <td>(PBW621/3/YR10/6*AVO</td> <td>(GRACKLE/HD2894)</td> <td>(DBW14/HD</td> <td>(KAUZ//ALTAR84/AOS/3/</td> <td>(K99O8/PBW534)</td> <td>(CHIR/3/SIREN//ALT</td>	(PBW621/3/YR10/6*AVO	(GRACKLE/HD2894)	(DBW14/HD	(KAUZ//ALTAR84/AOS/3/	(K99O8/PBW534)	(CHIR/3/SIREN//ALT
W621/5/PBW021/5/TVIENALVIENALVIENAL6*AVOCET/4*PBW343VIENALVIENALVIENAL72*PBW621VIENALVIENALVIENALVIENAL76*PG70M2920M2020M1000MD2180M202176*MC7047M2012/MARAMM2020/MARAMM10208/MARAMM2031MARAMM2051PM02076*MC7047M10202/MARAMM10207VIENALVIENALVIENAL76*MC7047M10204VIENALVIENALVIENALVIENAL76*MC7047M1030M1030M1080M1010M202/M1040476*MC7047M1030M1030M1030M1010M202/M1040476*MC7047M1030M1030M1040M10404M202/M1040476*MC7047M1030M1030M1040M10404M1040476*MC7047M1030M1040M1040M1040AM1040A76*MC7047M1040M1040M1040M1040AM1040A76*MC7047M1040M1040M1040AM1040AM1040A76*MC7047M1040M1040AM1040AM1040AM1040A76*MC7047M1040AM1040AM1040AM1040AM1040A76*MC7047M1040AM1040AM1040AM1040AM1040A76*MC7047M1040AM1040AM1040AM1040AM1040A76*MC7047M1040AM1040AM1040AM1040AM1040A76*MC7047M1040AM1040AM1040AM1040AM1040A76*MC7047M1040A	CET//4*PBW343/4/2*PB		2733//HUW468)	MILAN/KAUZ/4/HUITES)		AR84)
6*AVOCET/#*PBW343:::12*PBW61)12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS16*PS12*PS12*PS12*PS12*PS17*PS19*PS11*PS12*PS12*PS16*PS11*PS11*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS17*PS12*PS12*PS12*PS12*PS <td>W621/5/PBW621/3/YR15/</td> <td></td> <td></td> <td></td> <td></td> <td></td>	W621/5/PBW621/3/YR15/					
/2*PBW621PBW760U2942HD2967W11050HD3128U2841(MAC/TH.AC//3*PVNM)(ALD/CUC/URES/HD40)(MLAN/SA720/BABAX)(N489/HW501)(HUX559/BW527)MIRLO/BUC/4/2*PATOBKAUZ/5/HUTES/ULLLLK/KACHU/6/KACHU(KAUZ/5/HUTES/ULLLLANAC/CS/TH.SCLLLLLAMLAN/STURID/BUCLLLLLLBW233M1963M11050M1050M10140M104040M20/ALAR84/AD(AtHI)APRLII/CM5051(RE72TUKUR/FRE)MIAN/SAT230(D814/HD2733)M101AMAU/ALAR84/ADAL#1)MSEL4/FRE1/TUKELLLLLLHD3260BW373(FRANC0M)BM880BM880M1183M308*	6*AVOCET//4*PBW343/4					
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(NAC/TH.AC/3*PVN)(CS/TH.SC/3*PVN)/M(ALD/CU/LURES/HD1200(MILAN/S87230/BABAX)(VL849/HW5015)(HUW559/BBW527)MIRLO/BUC/4/2*PASTOISLO/BUC/4/URES/IMMHD278ISLO/BUC/4/URES/IMISLO/BUC/4/URES/IMISLO/BUC/4/URES/IMISLO/BUC/4/URES/IMR/S/KACHU/6/KACHU/KAUZ/5/HUTES/GISLO/BUC/4/URES/IMISLO/BUC/4/URES/IMISLO/BUC/4/URES/IMISLO/BUC/4/URES/IMR/S/KACHU/6/KACHU/KAUZ/5/HUTES/GISLO/CS/TH.SCISLO/SV/IMICO/BUC/4/URES/IMISLO/SV/IMICO/BUC/4/URES/IMISLO/SV/IMICO/BUC/4/URES/IMDBW233MILAN/S/TILHIISLO/SV/IMICO/BUC/4/UREMILIOSOMB0860MH1157BBW88(CHIBIA/PRLII/CM6553IRET27UKURU/FREMILAN/S87230IDBV14/HD2733MUNIA/IAUZ/ALTAR84/AD/S/SKAUZ/BAV92/4/UMISLO/AUTA/AUTA/HD/BABAX)/HUW468)CHTO/AMSEL)ISJ/IMLAN/KAUZ/4HAL#1)MSEL/FRET27UKUISLOITES)ITES)ITES)HD3226BRW373(FRANCUM)BW880BBW80WH138MD368*	PBW766	UP2942	HD2967©	WH1105©	HD3128	UP2841
MIRLO/BUC/42PASTORLO/BUC/4/URES/UVMHD2278R/S/KACHU/6/KACHU/KAUZ/S/HUTES/G-A/RAC/CS/TH.SCA/BAC/CS/TH.SC/3*PVN/3/MIRLO/BUC/4/ILAN/STILHIDBW233MP163M11050M10860/GHBIA/PRLII/CM553RET2/TUKUR//FRMILAN/S87230MB080/3/SKAUZ/BAO92/4/MUF2/AULALACHTO/A/BABA.3/H0468/Al#1MEL/4/FET2/TUKUF-UTES)/H0326BRW373(FRANCOLM)BM880BM880M1138	(NAC/TH.AC//3*PVN/3/	(CS/TH.SC//3*PVN/3/M	(ALD/CUC//URES/HD2160	(MILAN/S87230//BABAX)	(VL849/HW5015)	(HUW559/PBW527)
R/5/KACHU/6/KACHU    //KAUZ/5/HUTES/6/	MIRLO/BUC/4/2*PASTO	IRLO/BUC/4/URES/JUN	M/HD2278)			
YANAC//CS/TH.SC      /3*PVN/3/MIRLO/BUC      /3*PVN/3/MIRLO/BUC      /MILAN/5/TILH)      DBW233      MP163      MP167      MILAN/S7TLIKURU/FER      (MILAN/SPLI/CM0553)      FRET2/TUKURU/FER      MBABAX)      MSKAUZ/BAV92/4/MUN      MSEL/FRET2/TUKUR      MSEL      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR      MSEL/FRET2/TUKUR <td>R/5/KACHU/6/KACHU)</td> <td>//KAUZ/5/HUITES/6/</td> <td></td> <td></td> <td></td> <td></td>	R/5/KACHU/6/KACHU)	//KAUZ/5/HUITES/6/				
/*PVN/3/MIRLO/BUC/      /*PVN/3/MIRLO/BUC/      /*MILAN/5/TLHI)      DBW233    MP1963      /MIPA    MI1050      /MILAN/SPLI/CM6551    MER2/TUKURU/FRE      /MILAN/SPCI/MON    MER2/TUKURU/FRE      //SSKAUZ/BAV92/4/MUN    MER2/TUKURU/FRE      /MER2/TUKUR    //BABA3      //MILAN/SPCI/MON    //BABA3      //MILAN/SPCI/MON    //MILAN/SPCI/MON      //MILAN/SPCI		YANAC/7/CS/ TH.SC				
4/MILAN/5/TILHI)        DBW233      MP1963      WH105@      MD306@      WH157      DBW88*        (CHIBIA/PRLII/CM553)      FRET2/TUKURU/FRE      MILAN/S87230      (DBW14/D2733)      (MUNIA)      (KAUZ/ALTAR84/AO        /S/SKAUZ/BAV92/4/MU      T2/MUNIA/CHTO/A      /BABAX)      /HUW468)      CHTO/AMSEL)      S/3/MILAN/KAUZ/4/H        AL#1)      MSEL/FRET2/TUKUR      -      -      UTES)        L/FRET2)      -      -      -      -        HD3226      BRW373(FRANCOLM)      BW88@      BW88@      WH138      HD3086*		/3*PVN/3/MIRLO/BUC/				
DBW233      HP1963      WH105@      HD3086@      WH1157      DBW88*        (CHIBIA/PRLII/CM6553)      (FRET2/TUKURU/FRE      (MILAN/S87230      (DBW14/HD2733      (MUNIA/      (KAUZ/ALTAR84/AO        /3/SKAUZ/BAV92/4/MU      12/3/MUNIA/CHTO/A      //BABAX      /HUW468)      CHTO/AMSEL)      S/3/MILAN/KAUZ/4/H        AL#1      MSEL/4/FRET2/TUKUF      -      -      UTES)        U/FRET2)      -      -      -      -        HD3226      BRW373(FRANCOLIN)      BBW88@      BBW88@      WH138      HD3086*		4/MILAN/5/TILHI)				
(CHIBIA/PRLII/CM6553)      (FRET2/TUKURU//FRE      (MILAN/S87230      (DBW14/HD2733)      (MUNIA/      (KAUZ/ALTAR84/AO        /3/SKAUZ/BAV92/4/MUN      T2/3/MUNIA/CHTO//A      //BABAX)      //HUW468)      CHTO//AMSEL)      S/3/MILAN/KAUZ/4/H        AL#1)      MSEL/4/FRET2/TUKUR	DBW233	HP1963	WH1105©	HD3086©	WH1157	DBW88*
/3/SKAUZ/BAV92/4/MUN    T2/3/MUNIA/CHTO//A    //BABAX)    //HUW468)    CHTO//AMSEL)    S/3/MILAN/KAUZ/4/H      AL#1)    MSEL/4/FRET2/TUKUR    -    UTES)      U/FRET2)    -    -    -      HD3226    BRW3773(FRANCOLIN    DBW88©    DBW88©    WH138    HD3086*	(CHIBIA//PRLII/CM65531	(FRET2/TUKURU//FRE	(MILAN/S87230	(DBW14/HD2733	(MUNIA/	(KAUZ//ALTAR84/AO
AL#1)      MSEL/4/FRET2/TUKUR      UITES)        U//FRET2)      BRW3773(FRANCOLIN DBW88©      DBW88©      WH1138      HD3086*	/3/SKAUZ/BAV92/4/MUN	T2/3/MUNIA/CHTO//A	//BABAX )	//HUW468)	CHTO//AMSEL)	S/3/MILAN/KAUZ/4/H
U//FRET2)    BRW3773(FRANCOLIN DBW88©    DBW88©    WH1138    HD3086*	AL#1)	MSEL/4/FRET2/TUKUR				UITES)
HD3226 BRW3773(FRANCOLIN DBW88© DBW88© WH1138 HD3086*		U//FRET2)				
	HD3226	BRW3773(FRANCOLIN	DBW88©	DBW88©	WH1138	HD3086*
(GRACKLE/HD2894) #1//WBLL1*2/BRAMBL (KAUZ//ALTAR84/AOS/3/ (KAUZ//ALTAR84/AOS/3/ (PBW65*2/PASTOR) (DBW14/HD2733//HU	(GRACKLE/HD2894)	#1//WBLL1*2/BRAMBL	(KAUZ//ALTAR84/AOS/3/	(KAUZ//ALTAR84/AOS/3/	(PBW65*2/PASTOR)	(DBW14/HD2733//HU
ING/3/WBLL1*2) MILAN/KAUZ/4/HUITES) MILAN/KAUZ/4/HUITES) W468)		ING/3/WBLL1*2)	MILAN/KAUZ/4/HUITES)	MILAN/KAUZ/4/HUITES)		W468)

#### REML/BLUP to estimate G x E interaction in co-ordinated wheat trials

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PBW801	HD2967©	PBW677	HUW662
(PBW621/3/Yr10/6*Avocet//4*PBW	(ALD/CUC//URES/HD2160M/HD	(PFAU/MILAN/5/CHEN/A.SQUARROSA//	(DWR322/HUW300//PBW442/WH576)
343/4/ 2*PBW 621/5/PBW 621/3/Yr	2278)	BCN/3/VEE#7/BOW/4/PASTOR)	
15/6*Avocet// 4*PBW 343/4/2*PBW			
621)			
PBW800	WH1105©	HD3132	HD3109
(HD 2967/4/BW 9250*3// Yr10/6*	(MILAN/S87230//BABAX)	(WH542/UP2425)	(SOKOLL/3/PASTOR//HXL7573/2*BAU)
Avocet/3/ BW 9250*3// Yr15/6*			
Avocet/5/2*HD 2967)			
DPW621-50©	DBW88©	WH1154	DBW102
(KAUZ//ALTAR84/AOS/3/MILAN/	(KAUZ//ALTAR84/AOS/3/MILA	(WH337/HD2255//RAJ3077)	(WHEAR/KUKUNA/3/C801/3*BATAVIA//2*
KAUZ/4/HUITES)	N/KAUZ/4/HUITES)		WBLL1)
HD3086 ©	HD 3086©	PBW692	DBW101
(DBW14/HD2733//HUW468)	(DBW14/HD2733//HUW468)	(INQUALAB91*3/TUKURU//DBW18)	(CHAP10//2*SERI/RAYON)
HD 2967©		PBW698	HUW664
(ALD/CUC//URES/HD2160M/HD2		(BW9250*3/YR10/6*AVOCET/3/BW9250*	(PFAU/SERI.1B//AMAD/3/WAXWING)
278)		3//YR15/6*AVOCET)	
DBW 88 ©		HD3133	DPW 621-50©
(KAUZ//ALTAR84/AOS/3/MILAN/		(MILAN/S.8723O//BABAX)	(KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/H
KAUZ/4/HUITES)			UITES)
WH 1105 ©		HUW675	HD2967©
(MILAN/S87230//BABAX)		(ALTAR84/K AUZ// MILAN/H UW5 1 O)	(ALD/CUC//URES/HD2160M/HD2278)
		K1204	DBW 17©
		(K8434/PBW343)	(CMH79A.95/3*CNO79//RAJ3777)
		PBW695	WH1105(I) ©
		(PSN/BOW//MILAN/3/2*BERKUT)	(MILAN/S87230//BABAX)
		HUW666	
		(H UW2O6/ALTAR84//VE E/M I LAN)	
		HD2967©	
		(ALD/CUC//URES/HD2160M/HD2278)	
		DPW621-50©	
		(KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/	
		4/HUITES)	
		WH1105©	
		(MILAN/S87230//BABAX)	
		DBW88(I) ©	
		(KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/	
		4/HUITES)	
		HD 3086(I) ©	
		(DBW14/HD2733//HUW468)	

Table 1: Contd.....

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REML/BLUP	to	estimate	G	х	Е	interaction	in	co-ordinated	wheat	trial	ls
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Fable 2: Parentage details of genotypes for irrigated late sown conditions									
2017-18	2016-17	2015-16	2014-15	2014-13	2012-13				
PBW 771	DBW 173	DBW173	HI1604	HD3139	K1114				
(PBW550//YR15/6* AVOCET/3/2* PBW550)	(KAUZ/AA//KAUZ// PBW602)	(KAUZ/AA//KAUZ //PBW602)	(PFAU/SERI.1 B//AMAD/ 3/WAXWING/4/BABAX/LR42/ /BABAX*2/3/KUKURU)	(WBLL 1 //U P2338*2/VIVITSI)	(HP1731/HUW234)				
PBW752	PBW752	DBW172	DBW148	PBW703	HUW668				
(PBW621/4/PBW343//	(PBW621/4/PBW343//	(R9819/R9883	(BHRIKUTI/	(BW9250*3/YR10/6*AV	(UP2530/UP2425//				
YR10/6*AVOCET/3/3 *PBW343/5/PBW621)	YR10/6*AVOCET/3/3* PBW343/5/PBW621)	//DBW17)	35thIBWSN325)	OCET/3/BW9250*3//YR1 5/6*AVOCET)	WI10785/RAJ3765)				
PBW773	HI1617	DBW90©	PBW716	PBW702	NIAW1951				
(FRANCOLIN#1*2/K IRITATI)	(BAJ#1*2/HUIRIVIS#1 )	(HUW468/WH730)	(HD2967/7/CAL/NH//H567.71/3 /SERI/4/CAL/NH//H567.71/5/2* KAUZ/6/PASTOR)	(PBW533//YR15/6*AVO CET/3/PBW533)	(HD2781/NIAW301)				
DBW237	HD3059©	WH1124©	HUW688	DBW128	HD3091*				
(NAC/TH/AC//3*PVN	(KAUZ//ALTAR84/AO	(MUNIA/CHTO	(ATTI LA/PASTOR	(SITE/MO//PASTOR	(PICUS/3/KAUZ*2/				
/3/MIRLO/BUC/4/2*P ASTOR/5/KACHU/6/ KACHU)	S/3/MILAN/KAUZ/4/H UITES)	//AMSEL)	//H P 1 73 1)	/3/TILHI)	BOW//KAUZ/4/TILHI)				
WH1124©	DBW90©	HD3059©	K1314	WH1129*	WH1128				
(MUNIA/CHTO//AM SEL )	(HUW468/WH730)	(KAUZ//ALTAR84/ AOS/3/MILAN/KA UZ/4/HUITES)	(HD2402/K8565)	(CS/TH.CS//3*PVN/3/MI RLO/BUC/4/MILAN/5/TI LHI)	(PRL/2*PASTOR/4/CHOIX/ST AR/3/HE1/3*CNO79//2*SERI)				
DBW90 ©	WH1021©	WH1021©	PBW719	WH1021©	WH1130				
(HUW468/WH730)	(NYOT95/SONAK)	(NYOT95/SONAK)	(UP2556/PBW543)	(NYOT95/SONAK)	(PRL/2*PASTOR/4/CHOIX/ST AR/3/HE1*CNO79)				
HD3059©	WH1124©		DBW150	HD3059©	WH1124*				
(KAUZ//ALTAR84/A OS/3/MILAN/KAUZ/ 4/HUITES)	(MUNIA/CHTO//AMS EL )		(DBW1 6/GW322)	(KAUZ//ALTAR84/AOS/ 3/MILAN/KAUZ/ 4/HUITES)	(MUNIA/CHTO //AMSEL)				
WH1021©			UP2883	PBW590©	HD3119				
(NYOT95/SONAK)			((KAUZ//ALTAR84/AOS/3/M I LAN /KAUZ/4/HUITES)/ PBW 502)	(WH594/RAJ3814 //W485)	(TILHI/PASTOR)				
DBW173 (I) ©			HD3165	WH1124(I)©	UP2843				
(KAUZ/AA//KAUZ//P BW602)			(HD2824/CBW14)	(MUNIA/CHTO //AMSEL )	(CPAN4073/UP2382//OPATA/R AYON//KAUZ)				
			WH1179	DBW90(I)©	HD3117				
			(OASIS/SKAUZ//4* BCN/3/3*PASTOR)	(HUW468/WH730)	(HD2733/HD2824//DW1278)				
			K1312		WH1129				
			(PBW343/K0402)		(CS/TH.CS//3*PVN/3/MIRLO/ BUC/4/MILAN/5/TILHI)				
			K1313 (HUW468/K9107)		DBW90* (HUW468/WH730)				
			DBW147 (PBN142/DBW30)		PBW590© (WH594/RAJ3814//W485)				
			PBW718		PBW373©				
			(HD2855/PBW55O//PBW548)		(ND/VG1944//KAL/BB/3/YAC O'S'/4/VEE#5'S')				
			WH1021© (NYOT95/SONAK)		WH1021© (NYOT95/SONAK)				
			WH1124© (MUNIA/CHTO//AMSEL		DBW71 (I) © (PRINIA/UP2425)				
			HD3059@		HD3059(I) @				
			(KAUZ//ALTAR84/AOS/3/MIL AN/KAUZ/4/HUITES)		(KAUZ//ALTAR84/AOS/3/MIL AN/KAUZ/4/HUITES)				
			DBW90©						
			(HUW468/WH730)						

Table 3: Parentage deta	ails of genotypes for restricted in	rigated timely sown condi	tions		
2017-18	2016-17	2015-16	2014-15	2014-13	2012-13
BRW3806	HD3237	DBW179	MP1277*	UAS356	DBW74**
(NI5439/MACS2496)	(HD3016/HD2967)	(CNO79//PF70354/MU	(GW1901MP11	(UAS316/K9644//	(WBLLL*2/BRAMBLI
		S/3/PASTOR/4/BAV92	42)	NI5439)	NG)
		/5/FRET2/KUKUNA//F			
		KE12/0/MILAN/KAUZ //DPINIA/3/BAV02) M			
		ILAN/KALZI/PRIN			
		IA/3/BAV92)			
HD 3237	HI1619	NW6046	PBW644©	MP1277	PBW660**
(HD3016/HD2967)	(W15.92/4/PASTOR//HXL7	(D67./PARANA66.	(PBW175/	(GW190/	(WG6761/
	573/2*BAU/3/WBLL1)	270//AE.SQ U ARR	HD2643)	MP1142)	WG6798)
		OSA(320)/3/CUNNING			
		HAM/4 VORB)			
HI1620	HI1620	PBW737	HD3043©	DBW129	HD3122
(NAC/TH.AC//3*PVN/	(NAC/TH.AC//3*PVN/3/MI	(GONDO//WBLL1	(PJN/BOW//OP	(PFAU/MILAN/5/	(W15.92/4/PASTOR//
3/MIRLO/BUC/4/2*P	ACHIVE/VACHID	*2/10 KU KU/4/ CONDO//SHA5/WEA	ATA*2/3CRU	CHEN/A.SQUAR	HXL/5/5/2*BAU/5/W
KACHII)	ACHU/0/KACHU)	VFR/3/PASTOR)	ROSA	CN/3VFF#7/BO	DLLI)
initerite)		(EROS/THISTOR)	(224)//OPATA)	W/4/PASTOR)	
DBW252	CG1023	WH1142©	WH1080©	PBW706	WH1142
(PFAU/MILAN/5/CHE	(BOW/VEE/5/ND/VG9144//	(OEN/Ae.Sq.(TAUS)/F	(PRL/*2PAST	(MINO/898.97)	(OEN/Ae.Sq.(TAUS)/F
N/AE.SQ(TAUS)//BC	KAL/BB/3/YACO/4/CHIL/6/	CT/3/2* WEAVER)	OR)		CT/3/2*WEAVER)
N/3/VEE#7/BOW/4/P	CASKOR/3/CROC_1/AE.SQ				
ASTOR)	UARROSA(224)//OPATA/7/				
	PASTOR//MILAN/KAUZ/3/				
111/00	BAV92)	1102042@	WIII1140(D@	XXIII 1 40 4	1102120
HI1028 (EDET2*2/4/SNU/TD A	MP1318 (ATTH A/2*DCN//DAV02/2/		WH1142(1)©	WHI142* $(OEN/A \circ S \circ (TA))$	HD3120
$(\Gamma KE 12^{*}2/4/SINI/1KA)$ P#1/3/KAU7*2/TRAP/	(ATTILA/3*BCN//BAV92/3/ TII HI/5/BAV92/3/PRI /SAR	3CROC 1/A SOLIARR	(UEN/Ae.Sq. (TAUS)/FCT/3/	(UEIN/Ae.Sq.(TA US)/FCT/3/2*WF	(ATTILA*2/PDW03//D FRKUT)
/KAUZ/5/PFAU/WEA	A//TSI/VEE#5/4/CROC 1/A	OSA(224)/(OPATA)	2*WEAVER)	AVER)	ERROT)
VER//BRAMBLING)	E.SQUARROSA(224)//2*OP	0011(221)// 011111/	2	11 ( 210)	
	ATA)				
NIAW 3170	MACS6677	WH1080©		PBW644©	UAS347
(SKOLL/ROLF07)	(D67.2/PARANA66.270//AE	(PRL/*2PASTOR)		(PBW175/HD264	(TOB/ERA//TOB/CNO
	.SQUARROSA(320)/3/CUN			3)	67/3/PLO/4/VEE#5/5/
	NINGHAM/4/WBLL1*2/TU				KAUZ/6/FRET2/DWR
WU1142 @		DDW644@		WH1080@	102) MD2202
$(OEN/A \otimes Sa (TAUS)/E$	$(\mathbf{DPI} / * 2\mathbf{DASTOP})$	$PDW044 \otimes$ (PRW175/HD2643)			MP3346/NIAW1548)
(OLIV/AC.SQ.(TAOS)/T CT/3/2*WEAVER)	(IRE/2IASTOR)	(1 D W 175/11D2045)			(1011 3340/1014 1040)
WH1080 ©	PBW 644 ©			/ HD3043©	HD3121
(PRL/*2PASTOR)	(PBW175/HD2643)			(PJN/BOW//OPA	(MILAN//PRL/2*PAS
()	(==			TA*2/3CROC_1/	TOR/4/CROC_1/Ae.Sq
				A.SQUARROSA(	uarrosa(213)//PGO/3/B
				224)//OPATA)	AV92))
PBW644 ©	HD 3043©				HUW669
(PBW175/HD2643)	(PJN/BOW//OPATA*2/3CR				(ALTAR84/HUW206//
	UC_I/A.SQUARROSA(224)				MILAN)
HD 30/3 @	WH1142@				HD3070**
(PIN/ROW//OPATA*)	(OFN/Δe Sa (TAUS)/FCT/2/				(TAM200/TH1/3/HPFS
/3CROC 1/A.SOUAR	2*WEAVER)				(JUN//KAUZ)
ROSA(224)//OPATA)	· · · · · · · · · · · · · · · · · · ·				,
. ,					C306©
					(REGENT1974/3*CHZ
					//*2C591/3/P19/C281)
					PBW175©
					(HD2160/WG1205)
					HD3043©
					(PJN/BOW//OPATA*2
					$(3CKOC_1/Ae.Squarro sa(224)/(OPATA))$
					WH10800
					(PRL/*2PASTOR)
	*		-		(

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of F-test statistic observed for irrigated timely and late sown conditions though corresponding small value seen for restricted irrigation timely sown trials. Significant values of intercept at 0.01 per cent for first two conditions along with significant value for third condition. More over significant values (at P< 0.005) of slope for linear trend exhibited by irrigated timely and late sown trials with significant change at large values of probability for remaining condition. Desirable small value of CV had been portrayed by irrigated timely and late sown trials as compared to large value for restricted irrigated condition. Similar observations were recorded for root mean square error values. More or less same trend were seen for standard error for year as dependent factor.

Scatter plots of BLUP's of promising genotypes over the years were plotted to examine the co-efficient of determination ( $R^2$ ) and linear trend to assess progress in wheat production for irrigated timely, late and restricted irrigated timely sown conditions. Regression analysis for production revealed that under irrigated timely as well as late sown condition,  $R^2$  values were highly significant (P<0.01). Under the restricted irrigated timely-sown conditions, small value of  $R^2$  had seen.

Linear trend in the year-wise wheat production in different conditions revealed an increase in average production of promising genotypes in zone by the end of 2017-18. Production figures elevated to the level of 57q/ha (Fig. 1) for irrigated timely, of 50q/ha (Fig. 3) for irrigated late sown and 49q/ha (Fig. 5) for restricted irrigated timely sown trials. However, in 2012-13, average production was 51.6q/ha 42.3q/ha 45.6q/ha and by the end of period 0.62, 0.91 and 0.04 quintal yield could be added in subsequent trials respectively. Although highest yield levels of 58 q/ha (2016-17), 51 q/ha (2016-17) and

Source	SS	MSS	F value	Pr > F	Root MSE	R-Square	Coeff Var	Std error	t value	$\Pr >  t $
Model	54.21	54.21	9.11	0.0041	2.4395	0.1653	4.5359			
Error	273.76	5.95								
Total	327.97									
Parameter	Estimates									
Intercept								0.8029	64.27	<.0001
Year								0.2062	3.02	0.0041

Table 5: AN	OVA for irrigated	l late sown con	ditions							
Source	SS	MSS	F Value	Pr > F	Root MSE	R-Square	Coeff Var	Std Error	t Value	$Pr > \left  t \right $
Model	87.58	87.58	17.92	0.0002	2.2105	0.3452	4.8553			
Error	166.15	4.89								
Total	253.73									
Parameter	Estimates									
Intercept								0.8402	50.39	<.0001
Year	-		- <i>.</i>		,	··		0.2157	4.23	0.0002

Table 6: AN	OVA for restr	icted irrig	ated timely	sown condition	15	÷				
Source	SS	MSS	F value	Pr > F	Root MSE	R-Square	Coeff Var	Std Error	t Value	Pr >  t
Model	0.17	0.17	0.03	0.8668	2.4130	0.0010	5.2694			
Error	163.03	5.82								
Total	163.19									
Parameter	Estimates									
Intercept								1.0046	45.43	<.0001
Year						· · · · · ·		0.2579	0.17	0.8668

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lowest level nearly 40 q/ha (2014-15) were obtained in irrigated timely, late and restricted irrigated timely sown trials. Low values of CV for irrigated timely and late sown conditions suggested consistent improvement in production levels. More over erratic ups and down



Fig. 1 : Best linear unbiased predictors for promising genotypes for irrigated timely sown conditions



Fig. 2: Regression analysis of BLUP's for promising genotypes for irrigated timely sown



Fig. 3 : Best linear unbiased predictors for promising genotypes for irrigated late sown conditions

observed in restricted irrigated timely sown trials.

Study revealed that during studied period wheat production had progressed nicely in this bigger zone. Fitted straight-line trends by SAS software displayed in corresponding figures indicate that the linear growth was



Fig. 4: Regression analysis of BLUP's for promising genotypes for irrigated late sown



Fig. 5 : Best linear unbiased predictors for promising genotypes for restricted irrigated timely sown conditions



Fig. 6: Regression analysis of BLUP's for promising genotypes for restricted irrigated timely sown

observed under all sown conditions of the zone. During the year 2008-09, the base yield level was 5160, 4233 and 4564 kg/ha, respectively (as reflected by intercept of the equation). Restricted irrigated conditions of the zone expressed least yield increase over years with small values of  $\mathbb{R}^2$ .

BLUP analyses of wheat trials showed continuous increase in the grain yield of the genotypes developed by Indian co-ordinated wheat programme. This finding also corroborates with studies on co-ordinated wheat production estimated by BLUE approach (Mohan *et al.*, 2017). More over in present study factor analytic structure of the variance–covariance matrix of GxE interaction was considered to estimate the BLUP's of wheat genotypes (Smith *et al.*, 2015).

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## REFERENCES

Baretta, D., Nardino, M., Carvalho, I.R., Pelegrin, A.J., Ferrari, M., Szareski, V.J., Barros, W.S., Souza, V.Q., Oliveira, A.C. and Maia, L.C. (2017). Estimates of genetic parameters and genotypic values prediction in maize landrace populations by REML/BLUP Procedure.*Genetics & Molecular Research*, 16: 1-14.

**Burgueño, J., Crossa, J., Cornelius, P.L. and Yang, R.C.** (2008). Using factor analytic models for joining environments and genotypes without crossover genotype x environment interac- tion.*Crop Sci.*, **48** : 1291–1305.

Crespo-Herrera, L. A., Crossa, J., Huerta-Espino, J., Vargas, M., Mondal, S., Velu, G., Payne, T. S., Braun, H. and Singh, R. P. (2018). Genetic gains for grain yield in CIMMYT's semi-arid wheat yield trials grown in suboptimal environments *Crop Sci.*, **58** : 1890–1898.

**Cullis, B.R., Jefferson, P., Thompson, R. and Smith, A.B.** (2014). Factor analytic and reduced animal models for the investigation of additive genotype by environment interaction in outcrossing plant species with application to a pinus radiata breeding programme. *Theor. Appl. Genet.*, **127** : 2193–2210.

De Pelegrin, A.J., Carvalho, I.R., Nunes, A.C.P., Demari, G.H., Szareski, V.J., Barbosa, M.H., da Rosa, T.C., Ferrari, M., Nardino, M., dos Santos, O.P., de Resende, M.D.V., de Souza, V.Q., de Oliveira, A.C. and da Maia, L.C. (2017). Adaptability, stability and multivariate selection by mixed models. *American J. Plant Sci.*, **8**: 3324-3337.

Eileen Azevedo Santos, Alexandre, Pio Viana, Josie Cloviane, de Oliveira, Freitas, Daniele Lima Rodrigues, Rulfe Ferreira Tavares, Claudia Lougon Paiva and Margarete Magalha<sup>e</sup>es Souza (2015). Genotype selection by REML/BLUP methodology in a segregating population from an interspecific *Passiflora* spp. Crossing. *Euphytica*, 204 :1–11.

Gustavo, H.F., Oliveira, Camila B., Amaral, Flávia, A.M., Silva, Sophia M.F., Dutra, Marcela B., Marconato and Gustavo, V. Môro. (2016). Mixed models and multivariate analysis for selection of superior maize genotypes. *Chilean J.Agric. Res.*, 76:427-431.

Kelly, A.M., Smith, A.B., Eccleston, J.A. and Cullis, B.R. (2007). The accuracy of varietal selection using factor analytic models for multi-environment plant breeding trials. *Crop Sci.*, 47:1063–1070.

Kleinknecht, K., Möhring, J., Singh, K.P., Zaidi, P.H., Atlin, G.N. and Piepho, H.P. (2013). Comparison of the performance of best linear unbiased estimation and best linear unbiased prediction of genotype effects from zoned Indian maize data. *Crop Sci.* **53** : 1384–1391.

Mohan, D., Tiwari, V. and Gupta, R. K. (2017). Progression in yield and value addition of Indian bread wheat – An Analysis, *Indian J. Genet.*, **77** (1) : 16-24.

**Piepho, H.P., Möhring, J., Melchinger, A.E. and Büchse, A.** (2008). BLUP for phenotypic selection in plant breeding and variety testing. *Euphytica*, **161**: 209-228.

**Resende, R.M.S., Jank, L., do Valle, C.B. and Bonato, A.L.V.** (2004). Biometrical analysis and selection of tetraploid progenies of Panicum maximum using mixed model methods. *Pesqui Agropecu Bras.*, **39**: 335–341.

Smith, A., Ganesalingam, A., Kuchel, H. and Cullis, B. (2015). Factor analytic mixed models for the provision of grower information from national crop variety testing programmes. *Theor. Appl. Genet.*, **128**: 55–72.

Torres, F.E., Teodoro, P.E., Sagrillo, E., Ceccon, G. and Correa, A.M. (2015). Genotype x Environment interaction in semi prostrade cowpea genotypes via mixed models. *Bragantia*, 74:255-260.

